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Implicit versus explicit learning a novel skill for high school students and young gymnastics athletes

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Implicit versus explicit learning a novel skill for high school students and young gymnastics athletes

Abstract

The aim of the study was to compare the effects of implicit learning using dual task-paradigm, with explicit learning on a novel skill, and if the performance is maintained over a prolonged period of time. Two similar experiments were conducted, one at a high school with twenty-six adolescents (n=26, boys n= 15, girls n=11, age: 16 ± 0.66 years), and the other in a local gymnastics club with forty-four young child athletes from different groups (n=44, boys n=10, girls n=34, age: 10 ± 2.85 years). Both experiments consisted of a four-week front flip learning program, where participants underwent a total of two hours front flip practice between the pre- and post-test session. The intervention was followed by two retention tests three and six months after the post-test, in which the front flip was not practiced. The result in this thesis shows comparable improvements beyond baseline performance for both learning conditions over a six-month hiatus. However, the achieved level after the training intervention is not maintained in long-term retention. Although it was not a difference between implicit versus explicit learning, the performance development in the implicit groups for both adolescents and young gymnastics athletes continues to decrease after a six-month hiatus, whereas the performance developments for the explicit groups stops in decreasing after three months. Only the explicit group amongst adolescents showed greater improvements right after the training intervention, which is suggested to be a matter of age and maturation.

Introduction

The traditional theories of learning states that motor skills initially develop explicitly via cognitive processes that is generated by declarative knowledge for a learner to use. The explicit learning method is typically conscious accessible and can be described with words, for example when explaining how to perform a motor task (Reber, Walkenfeld, & Hernstadt, 1991). It is a common training method for teachers and coaches, because information can be given to learners quickly, this in turn facilitates rapid improvements in motor control (van Abswoude, Mombarg, de Groot, Spruijtenburg, & Steenbergen, 2021). Given that feedback and instructions are often provided verbally, explicit learning is thought to be highly dependent on cognitive resources, such as working memory.

The working memory contributes to the motor system because the manipulation of verbal information is employed when error information is used for the correction of movements and movement adaptations to varying task (Liao, Kronemer, Yau, Desmond, & Marvel, 2014). Working memory plays at least two important roles of motor performance; controlling attention to current performance, and inhibiting or suppressing attention to task-irrelevant stimuli (Dougherty & Hunter, 2003). However, individuals differ in their ability to retain and manipulate verbal information because the storage and processing components is limited by the capacity to process the sum of these activities (Cowan, 1999). Moreover, the maintenance and the ability to manipulate information is characterized by delayed maturation in adolescence (Conklin, Luciana, Hooper, & Yarger, 2007). However, the storage capacity for visuo-/spatial information peaks early in adolescence, whereas the capacity to store verbal information shows a more protracted development (Murre, Janssen, Rouw, & Meeter, 2013).

On the other hand, the implicit learning methods takes as starting point that an initial cognitive phase of declarative knowledge is not mandatory. The instructor does not give rules of execution, so the performer must encode all actions regardless of their potential outcome (Maxwell, Masters, & Eves, 2003). Learning to ride a bicycle is typically considered as an example of an implicit learned skill. One can ride a bike without needing to attend to or be aware of how to move the hands and feet. Practicing implicitly leads to motor skill acquisition that involve direct accumulation of procedural knowledge (Masters, van Duijn, & Uiga, 2019).

Procedural knowledge differs from declarative knowledge in that the movement is processed automatically, and independently of working memory (Robertson, 2016), which will restrict a learner´s opportunity to consciously control his or her movements (Votsis, Tzetzis, Hatzitaki, & Grouios, 2009).

Participating in gymnastics often involves performing movements in the presence of others. Further concerns about making a favorable impression might induce performance pressure, as sporting abilitiy has been associated with high social status, particular in terms of peer acceptance or popularity, in later childhood to middle adolesence (Knight & Holt, 2013). In pressured situations, performers have shown a drop in performance when provoked to consciously attend to their movements by pressure manipulations (Masters, 1992). Later, Masters and Maxwell (2008b) united the many views of conscious control with the "Reinvestment theory", as the "manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of ones movement during motor output". From the idea that pressure lead to an increased conscious attention to the performers own process of performance and thus disrupt the automatic nature of execution.

Masters (1992) tried to reconcile the theoretical and practical issues of the implicit and explicit learning methods, by proposing dual task paradigm. Which involves performing a concurrent attention-demanding secondary task during practice that is not associated with the task that is being learned. The rationale behind this paradigm is that the attentional resources needed to perform the primary motor task are higher for consciously controlled movements as compared to automatized movements. As such, the performance of a cognitive task is expected to interfere with performance on a consciously controlled motor task, but should not, or to a lesser extent, affect performance on an automatized motor task (Abernethy, 1988).

Some of the earlier evidence suggests that acquiring a skill implicitly has been found to be advantageous for several phenomena. For instance, it is less prone to interference from psychological stress (Kal, Prosée, Winters, & Van Der Kamp, 2018; Masters, 1992; Maxwell, Masters, & Eves, 2000b), independent of IQ (Reber et al., 1991), it has been found to converge with explicit learning over an extended period of time (Maxwell et al., 2000b), it remains stable under both anaerobic and aerobic fatigue (Masters, Poolton, & Maxwell, 2008), and experiences of successful movement performance (Capio, Poolton, Sit, Holmstrom, & Masters, 2013). Implicit learning, including dual-task paradigm, is in the later years increasingly applied in sports (Kal et al., 2018).

Much of the work on implicit learning originates from Masters (1992) who investigated why failure of expert motor skill is common in cases where performers are highly motivated to succeed. Subjects in the reported experiment were required to acquire a golf-putting skill, either explicitly or implicitly, by using the dual-task paradigm, and were tested under conditions of stress, induced by a combination of evaluation apprehension and financial inducement during a single trial. The study showed that the skill of performers with a small pool of explicit knowledge is less likely to fail under pressure than that of performers with a large pool of explicit knowledge. The authors then encouraged to reduce the use of explicit strategies amongst individuals with a high propensity towards reinvestment, because high reinvesters may be highly self-conscious and more likely to become stressed as a result of poor performance in conditions open to appraisal.

Later on, Maxwell, Masters, and Eves (2000a) investigated whether an extended period of practice with the dual-task paradigm would enable implicit learners to perform to the same level as individuals who learnt under explicit conditions. Participants practiced a golf-putting task in 3000 trials over eight days, and the performance of the implicit group remained below that of the explicit group throughout the learning phase. However, no significant differences were found between groups after three days retention. The author argues that the similar-shaped learning curves, demonstrates that these processes act in parallel, but the explicit process is rapid, whereas the implicit process is slow and requires much practice. Thus, suggesting that learning via implicit processes might benefit from highly constrained learning environments.

Furthermore, Poolton, Masters, and Maxwell (2007) investigated whether implicit performance is more durable over time than explicit motor performance. The participants went through 10 blocks of 10 trials, practicing a rugby passing throw as a novel skill. The retention of performance following a one-year interval without practice were seen in both conditions. However, as a result from a decay of declarative knowledge, the authors claim that implicit processes were left to support motor performance more effectively. Thus, the resilient performance amongst the explicit learners resulted from the consolidation of declarative knowledge as implicit memories in long-term storage.

Recently, Lola and Tzetzis (2020) investigated the effect of implicit and explicit methods on the acquisition and retention of a volleyball motor skill, and self-efficacy for novices. The participants underwent an intervention program consisting of 12 training units over four weeks, followed by a post-test measurement, and a retention-test one week later. The results showed that the implicit group achieved higher scores in the retention test for both motor performance and self-efficacy. Thus, the author recommends coaches to be aware of the type of feedback, as it improved the participants motor performance in volleyball, and subsequently their self-efficacy.

Collectively, these results reveal several advantages of learning a motor skill implicitly. However, since the subject’s performance level may have been shaped by earlier experiences, the baseline performance should be taken into consideration to measure the differences in the performance progression from the subjects' baseline performance level. Also, most of the evidence concerns early stages of learning. Suggesting that even though the skill is acquired, it is not to be considered truly learned until retention is demonstrated over time (Krakauer, Hadjiosif, Xu, Wong, & Haith, 2019). Thus, Poolton et al. (2007) is one of a few studies that tested the difference between implicit and explicit learning in long-term retention.

Therefore, the purpose of this study is to compare the effects of implicit learning using dual task-paradigm, with explicit learning on a novel skill, and if the performance is maintained over a prolonged period of time. It was hypothesized that the explicit learners will benefit from the feedback and instructions given to correct errors during practice, whereas the implicit learners must encode all actions regardless of their potential outcome without the contribution of working memory. But, in terms of retention it is expected that the implicit learners retain their front flip performance better, due to the direct accumulation of procedural knowledge. As the explicit learners may rely on the declarative knowledge to be retrieved from working memory resources if the performance has not been consolidated as procedural knowledge. Which makes them vulnerable to reinvestment.

Method

Two similar experiments were conducted in this thesis. The first experiment took place at a physical education class in a high school, and the second experiment took place in a local gymnastics club.

Participants

In the high school experiment, twenty-six adolescents (boys $n = 15$, girls $n = 11$) from Malvik sports school (age: 16 ± 0.66 years), participated based on their attendance in the physical education subject. All participants were novice gymnasts, but some had a bit of experience with the front flip as a motor skill from earlier. In the second experiment, forty-four children (boys $n = 10$, girls $n = 34$) from different groups in IL Sverre gymnastics club (age: 10 ± 2.85 years), participated based on their attendance in gymnastics as a leisure time activity. While twenty-eight of the participants, (age 8 ± 1.76) Regularly trained one hour a week. Sixteen participants, (age: 11 ± 1.43) regularly trained three hours a week. Although the participants had some experiences with the front flip, they had never been provided a full learning program before this experiment. Informed consent was obtained prior to testing from all participants and parents, with approval of the Norwegian Centre for Research Data (NSD) and conformed to the latest revision of the Declaration of Helsinki. The consent informed that participating in this project meant that the participants were not allowed to practice a front flip in any form as long as the experiment lasted.

Procedure

Both experiments consist of a four-week intervention between a pre- and post-test, followed by two retention tests, three and six months after the post-test in which the task was not practiced. The same warm-up procedures were used, to ensure the same starting point all tests. The participants had three attempts to perform a front flip per test, where the best attempt was used for further analysis. In addition, both experiments sought to induce pressure during the test by taking place in the presence of the other participants and gymnastic athletes, who worked as an audience. One standard digital camera, Sony Cybershot DSC-W380 (Tokyo, Japan) filmed all attempts from the participants in the same order at all tests, so that a gymnastics expert could evaluate their performance later. The camera was placed on a tripod 3 meters to the side of the mini tramp (figure 1). Footage was analyzed using Apple MacBook air (Cupertino, California, United States) that was disconnected from wireless internet, to prevent footage-materials going astray.

The performance was assessed by two assistants who were blinded to what group each candidate belonged to. The assessment of the front flip performance execution was based on FIGS scoring system known as “code of points” (De Gymnastique, 2006). However, an own code was designed to this experiment. The value of a perfect executed front flip was placed on 15 points in total, and deductions were related to errors in height, mid-air form, and landing. Errors were judged to be none, small, medium, or large and respective 0, 1, 3 and 5 deductions were applied.

Training procedure

A baseline test before the pre-test was conducted to get an indication of the participants performance level. After the pre-test, a stratified randomized selection ensured sufficient group comparability: an explicit learning group and implicit learning group. In the first experiment, twenty-six adolescents (n = 26) were divided into the explicit (n = 13) and implicit groups (n =

13). In the second experiment, forty-four children (n = 44) were divided into explicit (n = 22) and implicit groups (n = 22).

Each group underwent four weeks (120 minutes in total) of training between the pre- and post-test session. The groups were separated from each other during practice, because the implicit learners are supposed learn the skill without picking up the underlying rules of performance from the explicit learners´ training. Each group underwent 30 minutes with the intervention per practice, while the other group was training in another hall. In the high school experiment, the other group were practicing badminton. In the gymnastics experiment, the other group were practicing on uneven- and high bars. The task was constrained to enhance skill acquisition for both groups during practice (figure 1).

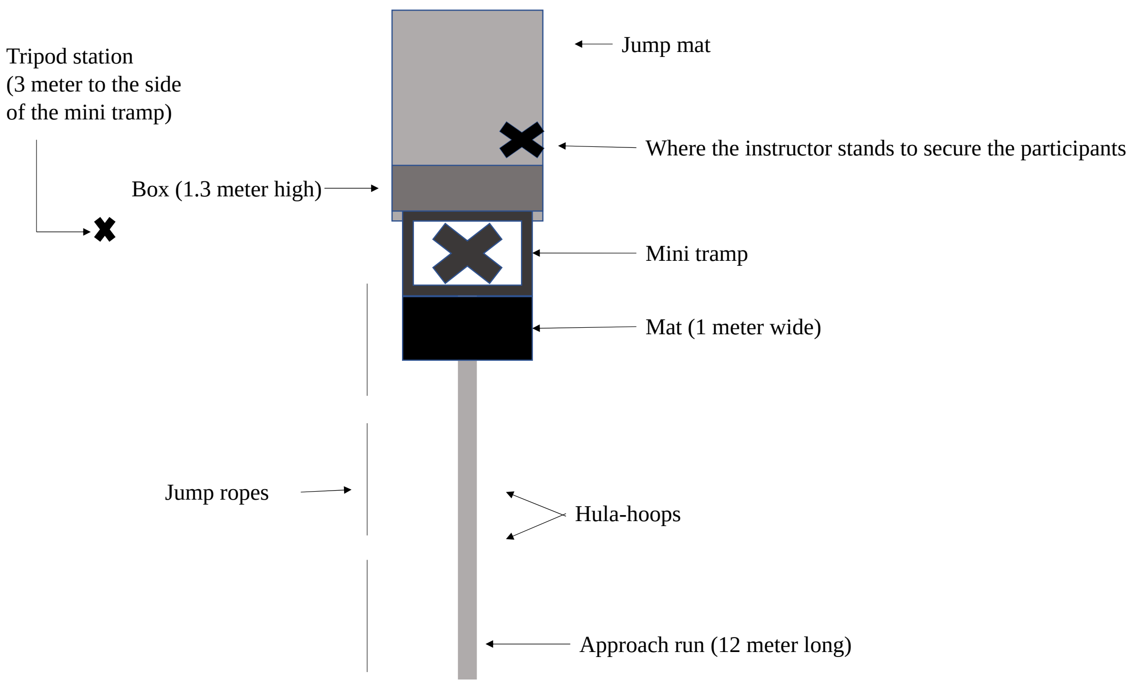

Figure 1 *Illustration of all the equipment used in the experiments*

First, a mat was placed in front of the mini tramp to make the participants have a long jump into the mini tramp. Second, a box was placed between the mini-tramp and the jump mat to make them jump higher. Third, hula-hoops were placed in a line with a certain gap between them. The distance in the gap increased, as the participant approached to the mini tramp. The purpose was to get the participant to run faster, as he or she approached the mini tramp. Fourth, jump ropes in three different colors to mirror traffic lights (red, yellow, and green), were placed alongside the approach-run to signal the increase in running speed from slow, faster to fast speed phase. Note, that the tests did not include this equipment to constrain the task. Only, the approach run, mini tramp, jump mat, security from the instructor and the digital camera, which was placed on the tripod station, three meters away to film the participants. The explicit group got standardized feedback presented through a set of specific instructions on how to do a front flip: "Run faster, as you approach the mini tramp", "have a long jump into the mini tramp", "jump high", "engage the spin on the apex of the jump", "grab your knees", and "open up before landing". On the contrary, the implicit group got no such feedback, but the mini tramp safety instructor asked the participants, a relatively simple mathematical additive solving, below 100, before each attempt at a randomly order. Some of the additives were more difficult than others, such as: 31 + 19 and 20 + 30.

Statistical analysis

To assess the effects of using the learning methods in a high school set up and a gymnastics club set up, a 3-way ANOVA; 2 (methods/groups) x 4 (tests) x 2 (experiments), with repeated measures was used to evaluate front flip performance. In addition, a 2 (methods) x 4 (tests) per experiment was used to investigate the effect per experiment. Post-hoc testing using Holm-Bonferroni probabilities adjustment was used to locate significant differences. To investigate the scores between the judges a 1-way ANOVA with repeated measures was used to investigate an eventual systematic bias between the judges together with the limits of agreement, which was calculated using an intraclass correlation coefficient (ICC). The interpretation of ICC were that values below 0.5 indicated poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.9 good reliability, and any value above 0.9 indicates excellent reliability (Koo & Li, 2016). Effect size was evaluated with (Eta partial squared) where $0.01<\eta^2<0.06$ constitutes a small effect, a medium effect when $0.06<\eta^2<0.14$ and a large effect when $\eta^2>0.14$ (Cohen, 1988). Where the sphericity assumption was violated, the Greenhouse-Geisser adjustments of the p-values were reported. The level of significance was set at $p \leq .05$. Statistical analysis was performed in SPSS version 27.0 (IBM Corporation, Armonk, NY, USA).

Results

In the high school experiment, the overall difference in points between the judges was significant (F= 1252.3, p = .001* η^2 = .981), on all test occasions. However, the intraclass correlation coefficient is .838, which indicates good reliability (figure 2A). In the second experiment, the overall difference in points between judges was also significant (F = 192.2, p

= .001*, η^2 = .817), on all test occasions. Yet, the intraclass correlation coefficient is .953 (figure 2B).

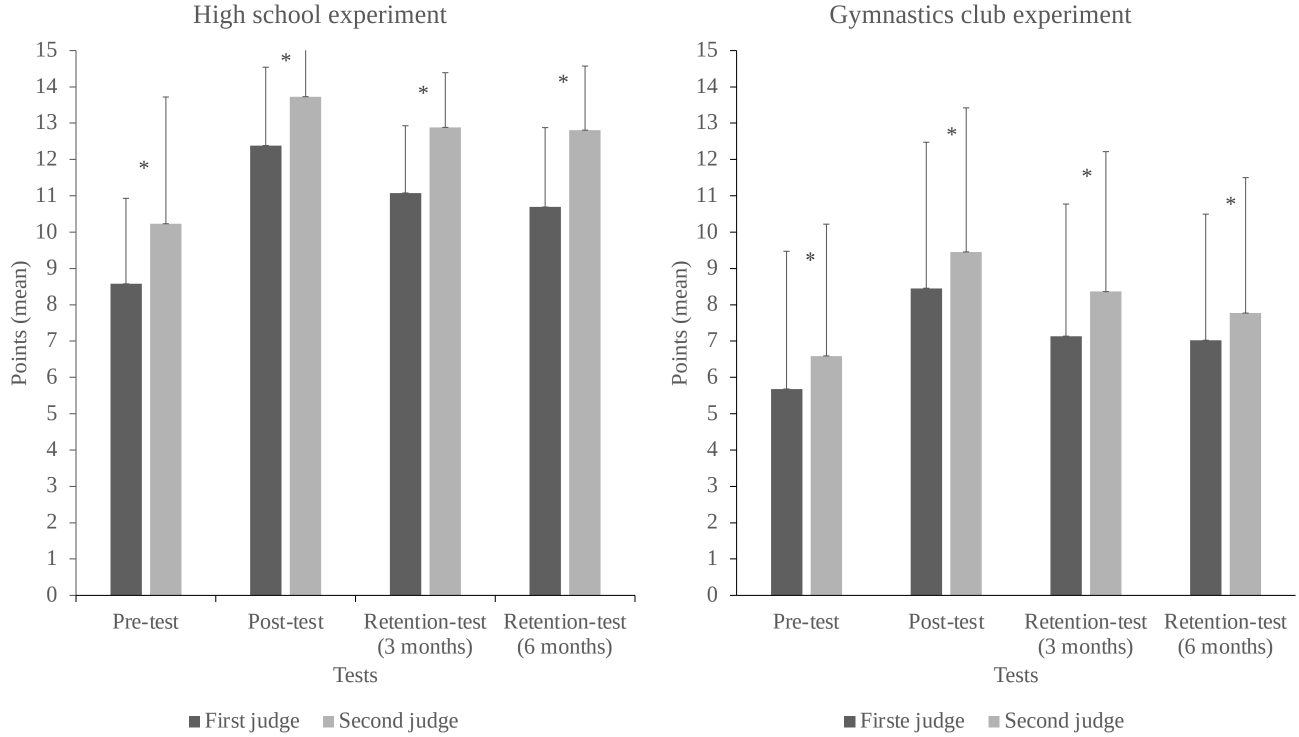

*Figure 2A (left) and 2B (right) Mean overall score between judges in both experiments at each test occasion. * Indicates a significant difference between judges on a p<0.05 level.*

Due to the high internal consistency between the judges, the average score between the two was used for further analysis. With all observations taken into consideration from both experiments, a significant difference between all tests occasions was found (F = 618.4, p = .001, η^2 = .904). Also, a significant effect between experiments was found (F = 25.8, p = .001, η^2 = .281). But no significant group effect (implicit vs. explicit) was found (F = .022, p = .883, η^2 = .001).

However, a significant interaction effect (F = .5.1, p = .008, η^2 = .072) was found indicating different developments of the different groups over the two experiments (see figure 3). Post hoc testing showed that for the explicit groups of both experiments taken together, a significant effect between all test occasions (F = 58.5, p = .001, η^2 = .733) was found, except not between the two retention-tests (p = .361). As for the implicit groups of both experiments taken together, a significant effect between all test occasions was found (F = 32.3, p = .001, η^2 = .602). Since the experiments had different outcomes, ($F = 4.6$, $p = .001$, $\eta^2 = .733$) a closer look into each experiment was investigated.

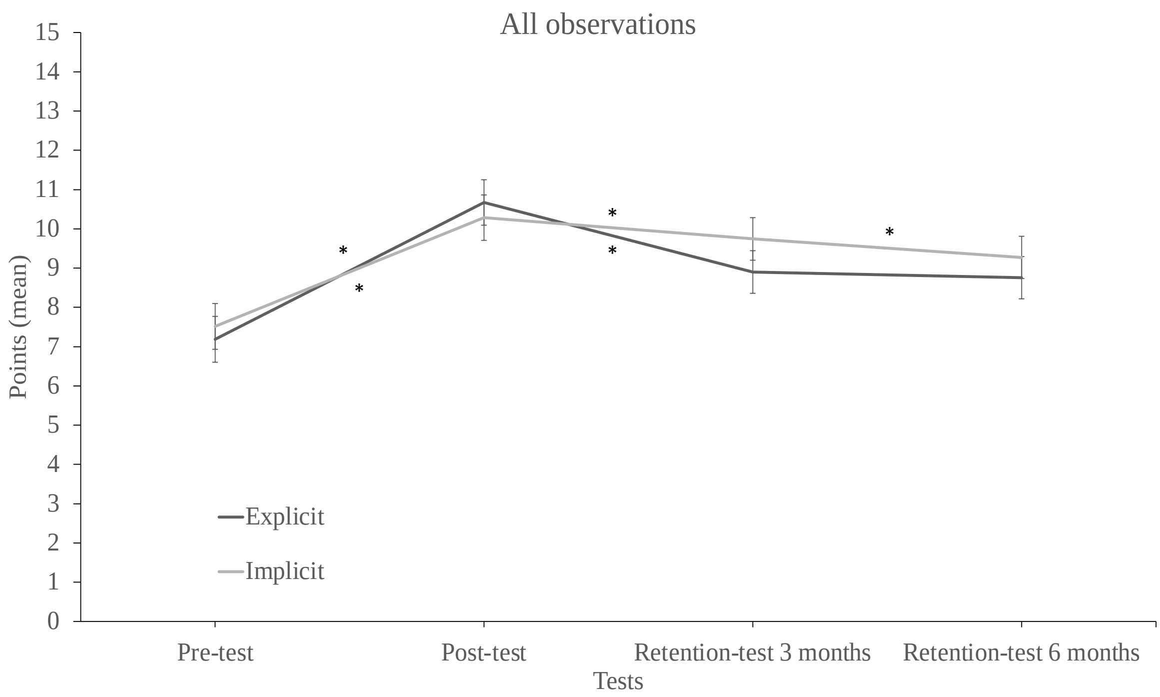

*Figure 3 Average scores from two judges on front flip performance for each test for the implicit and explicit groups, including all subjects from both experiments. * Indicates a significant difference with the previous test occasions on a p<0.05 level.*

When specified per experiment, the high school experiment showed a significant difference between all test occasion ($F = 1252.3$, $p = .001$, $\eta^2 = .981$). But it was not found a significant difference between groups ($F = 1.1$, $p = .299$, $\eta^2 = .045$). However, a significant interaction effect ($F = 48.8$, $p = .001$, $\eta^2 = .670$) was found, indicating a different development between groups (Figure 4A).

Post hoc testing showed that for the explicit group, a significant effect between all test occasions ($F = 22.6$, $p = .001$, $\eta^2 = .755$) was found, except between the two retention-tests ($p = .858$). Also, the increasement between the pre-test and post-test was greater than the implicit group, to a point in which the difference between groups was significant ($p = .019$) at the post-test. Then the performance decreases after the post-test to a point in which the difference between groups converge, and thus is no longer significant ($p = .477$), see figure 4A.

In the implicit group, a significant effect between the pre-test and the post-test ($F = 8.1$, $p = .001$, $\eta^2 = .523$) was found, but not between post-test and the first retention-test ($p = .045$), and not between the two retention-tests (p = .059). However, it was found a significant difference between the post-test and the last retention-test (p = .019).

The gymnastics experiments showed significant differences between all test occasions (F = 187.1, p = .001, η^2 = .817). But it was not found a significant difference between groups (F = .7, p = .414, η^2 = .016). However, a significant interaction effect (F = 119.3, p = .001, η^2 = .740) was found indicating a different development between groups (Figure 4B).

Post hoc testing showed that for the explicit group, a significant effect between all test occasions (F = 40.4, p = .001, η^2 = .751) was found, except between the two retention-tests (p = .184). As for the implicit group, a significant effect between was found between all test occasions (F = 35.3, p = .001, η^2 = .726).

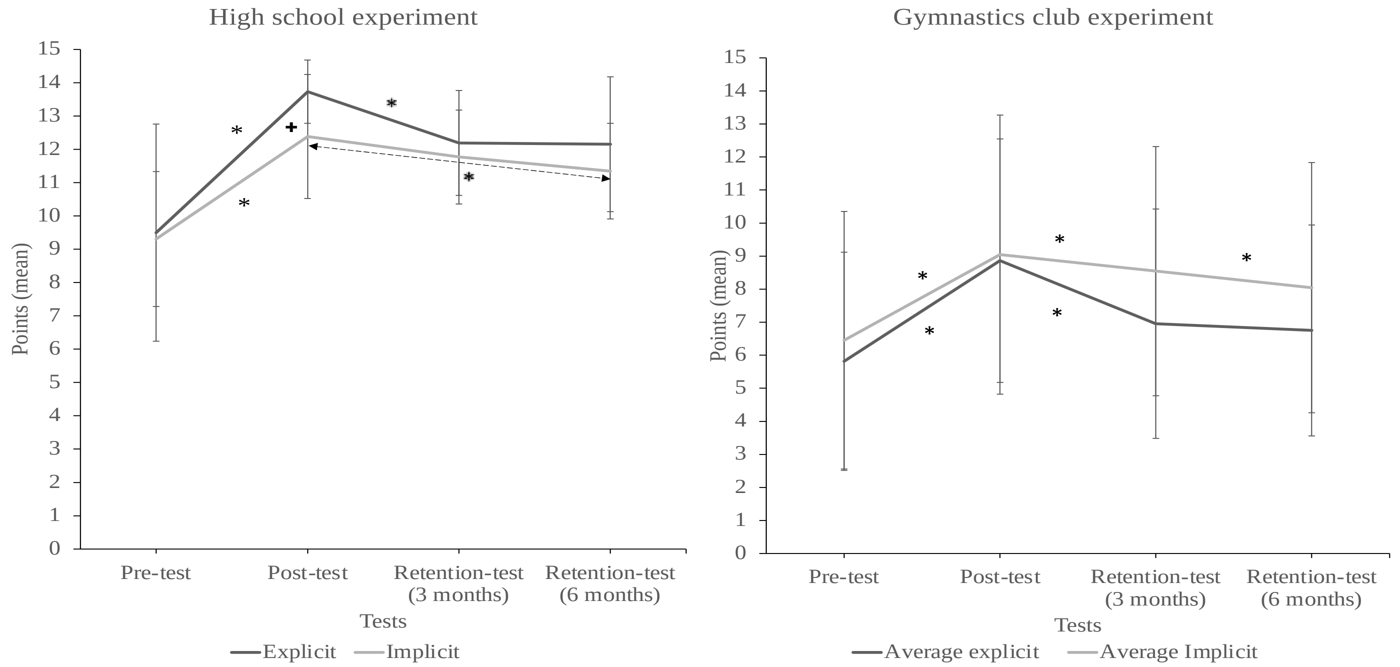

*Figure 4A (left) and 4B (right) Difference within groups to measure progress, as well as between groups to measure difference, based on the mean scores from two judges. * Indicates a significant difference with the previous test occasions on a p<0.05 level. ✚ Indicates significant difference between groups at the test occasion on a p<0.05 level.*

Discussion

The aim of the study was to compare the effects of implicit learning using dual task-paradigm, with explicit learning on a novel skill, and if the performance is maintained over a prolonged period of time. The result in this thesis shows lasting improvements beyond baseline performance for all participants at average over six months of time. However, the performance decreases in both groups after the post-test. Furthermore, this performance decrement stabilizes in the explicit group after three months, but not in the implicit group. Even though no statistical difference was found between the groups, it was a difference between the experiments. As the adolescents performed the front flip on a higher level than the young gymnastics athletes. Also, the experiments had different outcomes, with different developments of the implicit or explicit learners.

Amongst adolescents in the high school experiment, the explicit learners had a greater improvement in front flip performance compared to the implicit group to the post-test. However, the explicit groups had a greater decrease in performance after the post-test, which results in a convergence between the learning methods after three months. Amongst the young gymnastics' athletes, the differences in front flip performance between the implicit and explicit groups remained similar in the post-test. Although, the performance between groups remained comparable throughout the experiment, the performance decrement in the explicit group stabilizes after three months, but continues to decrease for the implicit group after six months.

The number of trials turned out to be enough for the participants to build a sufficiently large pool of positive action outcomes, which allowed stabilization of the memory trace to consolidate into procedural knowledge, regardless of whether they were practiced as implicit or explicit learners. This is especially important for the implicit learners, as according to Berry and Broadbent (1988) must encode all action-outcomes. Thus, the improved performance is a result of a gradual build up in positive outcomes, whereas explicit learners benefit from the correction of errors, which helps with the conscious selection of positive action-outcomes and avoidance of negative ones.

Guided by previous findings from Maxwell et al. (2000a), the task was constrained in both groups to minimize errors during the acquisition of the front flip. When starting easy and then increasing task difficulty gradually, participants progressed to a point in which the equipment were not necessary. Also, the changes in the task may not always have been consciously noticed. In this way, the learners are less likely to form and test hypothesis and thus build procedural knowledge directly. For example, participants who may have lacked the strength required to gain optimal height in their jumps, could have benefited by being provided with hula hoops in the approach run. Because a simple way to increase a gymnasts jump height is by moving faster in the approach run, as the vertical velocity is directly related to the ability of the gymnast to utilize the horizontal energy generated during the run, and the mini tramps' elastic properties to develop vertical momentum (Prassas, Young-Hoo, & Sands, 2006). This may have helped the participants to regulate their movements, through practice.

This is supported from the ideas of dynamical systems theory, which argues that repeated movement patterns permits adaptive motor behavior, as self-organizing patterns formed in the interactions between constraints associated with the learner, environment and movement task (Thelen & Smith, 1994). Thus, In terms of Edelman (1993) theory of neuronal group selection, this may be due to the attunement of the learner's movement through practice, as the selection of neural groups through experience has improved the efficiency of synaptic connections, which results in integration of a current state with long-term memory traces. Also, the principle of specificity, holds that the closer the training routine is to the requirements of the desired outcome, the better will be the outcome (Magill & Anderson, 2010).

Similar findings were found by Maxwell et al. (2000a) , that used dual-task paradigm for the implicit learners to investigate whether an extended period of practice would enable implicit learners to perform to the same level as individuals who learnt under explicit conditions. No statistically reliable differences were found between groups during the delayed retention-test. However, their experiment was eight days long, and the delayed retention test was 72 hours after the learning phase. In which is much shorter than the experiment in this thesis.

However, Poolton et al. (2007) showed a retention of performance at a comparable level between implicit and explicit learning groups after a one year hiatus. The performance retention in both treatment conditions was unaffected by the hiatus, in which the participants had no further experience of the motor task. Also, the author measured the amount of declarative knowledge amassed during the intervention, in which the participants conveyed less task relevant declarative knowledge of their motor performance a year later. The authors speculated that the comparable performance between groups, resulted from the consolidation of declarative knowledge as implicit memories in long-term storage. Yet, memory consolidation infers that knowledge is not fixed at the moment of learning but stabilizes and develops over time (Krakauer & Shadmehr, 2006). In this thesis, the performance decreases after the post tests in both groups (figure 3).

Suggesting that the performance level achieved after the learning phase have decayed from the highest level performed at the post-test, without consolidation as procedural memories. Thus, it is possible that the number of trials was still insufficient to allow the performance of the implicit and explicit learners to be maintained at the level achieved after the training program. If so, then further practice is required to build a larger pool of action-outcomes to allow the performance level achieved to consolidate into long-term procedural memories. Nevertheless, the performance decrement has stabilized for the explicit group after three months, which may suggest that the performance development encountered a kind of baseline foundation of procedural knowledge, whereas the performance continues to decrease after three months in the implicit group, suggesting that for this group, the baseline foundation is not yet met.

Even though very few studies have considered long-term retention in the difference between implicit and explicit motor learning. Support from more objective methods done by Zhu, Poolton, Wilson, Maxwell, and Masters (2011), found alpha bandwidth coactivation between the left temporal region (T3), which is understood as the verbal-analytical region, and the frontal midline region (Fz), that is understood as the motor planning region, through EEG measurements. That explicit learners adopt more verbal, conscious control of their movements than implicit learners. Thus, increased movement automaticity is characterized by reduced coherence between left-sided verbal analytical brain regions and central premotor brain regions.

However, a review Ludyga, Gerber, and Kamijo (2022) show that working memory relies on interactions between multiple brain regions, including the prefrontal cortex. Thus, the prefrontal cortex has been associated as a pathway to exercise-induced improvements due to both maintenance of goal-relevant information, as well as the processing of bottom-up sensory inputs via top-down knowledge (Miller, Lundqvist, & Bastos, 2018). However, its development is distinct from other regions involved in working memory as the structural and functional maturation of the prefrontal cortex continues throughout adolescence (Chini & Hanganu-Opatz, 2021). This implies a developmental difference in the ability to process information between adolescents and children.

It was observed that the adolescents had a higher baseline performance level, and thus a better front flip accuracy than the young gymnastics athletes. This may suggest that the adolescents have a better foundation for utilizing the procedural knowledge in comparison to the younger participants. Probably because the adolescents is older, in which increases the chances of having some earlier experiences that might have developed a greater foundation for utilizing this procedural knowledge.

It could also be a matter of physical growth and development. In accordance with Brown, Patel, and Darmawan (2017) paper on "participation in sports in relation to children and adolescents growth and development". The young gymnastics athletes, whose age is an average of 10 years old, experiences rapid changes in physical growth and motor skills, and the physical performance differences are significantly influenced by age at onset of puberty. Which may cause some challenges with enhancing their gross motor skills as they may experience transient incoordination between anthropometric measures. Suggesting that some may find it difficult to adjust to the somatic growth spurt in performing the front flip. As for the adolescents, whose age is an average of 16, may demonstrate greater motor coordination to manage a more accurate front flip performance. However, this age is also characterized by continued increases in anthropometric measures, strength etc.

Additionally, it could be due to a difference in the ability to process the sensory feedback from afferent signals in the dynamic interplay between the task and the participants. As for the young gymnasts, if the prefrontal cortex is not yet fully developed, they may experience a more immature ability to encode the sum of information from the task, regardless of being learned as implicit or explicit learners. As the maintenance and the ability to manipulate information is characterized by delayed maturation in adolescence (van Abswoude, Buszard, van der Kamp, & Steenbergen, 2020).

This may suggest how the explicit learners in the high school experiment benefitted from the set of instructions that were provided during the training intervention. As they gain conscious control over movement information that facilitates improvements, and to prevent or alter automatic responses that are inapproriate (Reber et al., 1991). This requires the explicit group to update their movement patterns to the task constraints, which depends on their ability to use the working memory capacity. For instance the capacity to carry out the type and volume of instructions that were provided, which is further influenced by the requirements of what to do with the instructions in the task environment ("have a long jump into the mini tramp, to get a sufficient height, in order to engage the spin at the apex of the jump"). Accordingly, this may suggest that the adolescents had better prerequisites, than the young gymnastics athletes, and thus have a better capacity in the working memory to carry out the necessary requirements in the task.

Similar findings were found by Maxwell et al. (2000a). Although the participants age ranged between 20 and 29 in their study, the treatment groups performed comparable throughout the project. There were significant differences in the development between explicit and implicit learning groups during the first block of the learning phase. But no significant difference between the groups and thus no convergence found in the 72-hour delayed retention-test. Thus, this finding differs from this thesis, as the explicit group in the high school experiment had a greater drop in performance after the post-test relative to the implicit group, to a point where the performance in both groups converge after three months.

As previous mentioned, it is possible that the number of trials was still insufficient for the explicit learners, because the procedural knowledge generated by the continued applications of the specific set on instructions may not have been manifested enough for the movement to be successfully consolidated into procedural memories and released from declarative control. Moreover, Zhu et al. (2011), showed that the medial temporal lobe-dependent declarative systems acquire new information quickly and flexibly but is less long-lived.

Furthermore, as students in high school meet rewards as grades potentially deciding their future employment opportunities. This may have induced performance-pressure, in which could have led to reinvestment. The explicit learners could then have tried to consciously attend more closely to the front flip performance in a manner that causes the paradoxical effect of disrupting its automaticity. By breaking the skill down, to the step-by-step of instructions that were provided ("run faster as you approach the mini tramp", "have a long jump into the mini tramp", "jump high" etc.), may have fragmented the transitions between the front flips automatic nature, which creates an opportunity for errors. Consequently, the chance of being exposed in front of their peers, could affect one to doubt his or hers capabilities. Thus, shying away from the task because it may be viewed as a personal threat (Bandura & Wessels, 1994).

The implicit learners might have benefited in this manner, as they did less likely form and test hypotheses, and hence built up less declarative knowledge. In which the dynamic interplay between the task and the participants repeated performance of an adequate front flip, may have led to the direct consolidation of procedural knowledge.

The dual-task paradigm could also have played an important role of bypassing the contribution of working memory, as the participants may have failed to be distracted by task-irrelevant cues, such as how the audience perceived their performance, because they were solving additives instead. Which is supported by Poolton et al. (2007), who showed that the implicit learners failed to be impacted by working memory distractions. On the contrary, suggesting that the explicit learners may purposefully rely on declarative knowledge to control their movements, believing that this is the most efficient way to offset task irrelevant cues, such as perceived feelings of discomfort.

Furthermore, DeCaro, Thomas, Albert, and Beilock (2011) who investigated if pressure induces distractions or explicit monitoring that hurts performance for explicit learners that is heavily dependent on attentional control. Suggested that skill failure depends on how the environment influences attention, and the extent to which skill execution depends on explicit attentional control.

In this manner, the dual-task paradigm might have created more positive learning experiences, by distracting the students focus away from a performance-oriented environment to a more mastery-oriented environment. Because it could make the students unaware of errors during practice, rather than being corrected for mistaken attempts. In which may be particularly beneficial for children with lower motor proficiency, or to insecure students involved in physical activity because they feel more vulnerable than others (Kambas et al., 2004).

This is supported by findings from Lola and Tzetzis (2020), who investigated the effect of explicit and implicit learning, by using dual-task paradigm on motor performance and self-efficacy in novice participants. The improved motor performance of both groups had a positive effect on their self-efficacy levels, but the implicit group scored higher in both motor performance and self-efficacy, than the explicit group. The author suggested that the dual-task paradigm gave a vague belief in their ability to execute the specific task, but also less meta-knowledge, with no rules to recall. However, it made the task “look” easier, creating a concept of successful execution and a sense of pleasure.

This may be equally important, but especially relevant for the young gymnastics’ athletes, as participating in gymnastics as a leisure time activity, is not necessarily influenced by evaluations of progress, initiative, and performance. Thus, in accordance with Logan et al. (2019), trial and errors are a common part of children's active play. In which, children predominantly rely on implicit learning strategies, as it more closely sembles their prefered mode of learning. Moreover, because they learn skills through active play that is fun and appropriate, through a series of trials and errors. In which movements are corrected and refined until they reach optimal accuracy and timing (Trofimova, Mottaz, Allaman, Chauvigné, & Guggisberg, 2020).

Another finding by, Reddy et al. (2018) show that in early motor learning, the activation of prefrontal cortex is used more flexibly when procedural knowledge is increased, as a period of practice was indexed by a decrease in prefrontal cortex activation despite the progress in motor skill acquisition process. Suggesting that as the learners increases in progress, the procedural knowledge overrides the contribution from working memory, without the verbal analytical control of their movements.

Furthermore, if the prefrontal cortex is not yet fully developed for the young gymnastics' athletes, the cognitive effort during practice may have exceeded at least some of the explicit learner's optimal capability to use their working memory capacity. Thus, if the sufficient resources are not available, or for instance occupied in inhibiting attention to task-irrelevant cues, such as how their actions are perceived, this could have led to an overload. Which, may interfere with the learner's ability to process the additional cognitive demands that exceeds the available working memory resources. Especially those with reduced information-processing abilities, if the explicit rules demand too much cognitive effort than the working memory resources manage to cope with (Sullivan, Kantak, & Burtner, 2008). Accordingly, the combination of low working memory capacity and to high volume of verbal instructions that necessitated updating movement patterns might have resulted in a poorer ability to use the instructions.

Blinded outcome assessors were used to prevent detection bias. It was appointed four external gymnastics-licensed trainers, two in each study. The judges were without in-depth knowledge of motor learning theories, nor aware of the research question and expected results. This gives the opportunity to calculate limits of agreement between the two in each experiment, to show how accurate the measurements are. Even though there was a clear difference between the judges, with one judge being stricter than the other in both experiments. The judges did mostly agree to the scores throughout the project, which gave the opportunity to measure the average score between the two for the further analysis.

There were some limitations with the present study. Although it would have been preferable with the same judges measuring both experiments, it was different judges in the experiments. This means that the comparison between the two experiments is not realistically, because it was not compared by the same judges. However, the code designed for this experiment had an interval of 2 points between the errors that were being deducted, which gave all judges a better opportunity to agree on how many deductions that should be applied to all the measured attempts. Also, the criteria allowed individuals with some experience to participate. Meaning that some are likely to bring tacit knowledge to the experiment, in which the explicit learners is not to be considered as purely explicit learners. Additionally, since the design of this experiment did not measure the precise mechanisms for long-term retention, further research is warranted. For example it could be beneficial to measure the explicit knowledge, providing a questionnaire like "The movement Specific Reinvestment Scale" by Masters and Maxwell (2008a), to all participants between all test-occasions, to get a more fine-grained assessment in whom that relies more or less on the accumulated declarative knowledge.

Conclusion

Most of the evidence between implicit versus explicit learning, concerns early stages of learning. Therefore, the aim of the study was to compare the effects of implicit learning using dual task-paradigm, with explicit learning on a novel skill, and if the performance is maintained over a prolonged period of time.

The result in this thesis shows comparable improvements beyond baseline performance for both learning conditions over a six-month hiatus. However, the achieved level after the training intervention is not maintained in long-term retention. Although it was not a difference between implicit versus explicit learning, the performance development in the implicit groups for both adolescents and young gymnastics athletes continues to decrease after six months, whereas the performance developments for the explicit groups stops in decreasing after three months. Only the explicit group amongst adolescents showed greater improvements right after the training intervention, which is suggested to be a matter of age and maturation.

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